Early Life History of Sauger in Missouri River Reservoirs

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Early Life History of Sauger in Missouri River Reservoirs

by

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ABSTRACT

The sauger *Sander canadensis* is a native predator in the Missouri River system that has experienced widespread declines across much of its range. To better understand sauger ecology and identify management strategies, we studied the sauger population in the Lewis and Clark Reservoir System. This population remains relatively abundant and stable. Moreover, the diversity of habitat in this system (reservoir, remnant reach, and delta) represents conditions found throughout much of the Missouri River. We examined sauger early life history (from spawning females through the juvenile period) to better understand the ecology of this population. Female sauger of intermediate age (4-6) and large sizes (460-520 mm) had the highest quality (caloric content and egg diameter) eggs. We did collect one older female sauger (age 11) that contained eggs of reduced quality, but retained higher fecundity. Thus, it appears that older sauger females might experience a reduction in egg quality. Larval sauger were not collected in the riverine habitats of this system (delta, tributaries, or remnant reach), but were encountered in the reservoir in low abundance. Our sampling method (circular larval trawls) was ineffective for larval sampling in this system. We sampled juvenile sauger throughout the delta and reservoir habitats of this system, but sample sizes were too low to quantify habitat-specific patterns of growth and abundance. Sauger were collected from all sites and all time periods, suggesting that young sauger disperse throughout the delta and reservoir after the larval period. We evaluated the efficiency of four sampling gears (mini-fyke nets, seines, small mesh gill nets, and electrofishing) and experienced the most consistent catches with electrofishing (although all gears collected sauger). Although our catch of young sauger was generally low, we collected many other fishes during our sampling that allowed us to compare fish species diversity between the delta and reservoir habitats.

The expansive and expanding delta at the confluence of the Niobrara and Missouri rivers in Lewis and Clark Reservoir provides diverse aquatic habitat that is somewhat similar to the historic Missouri River and to remnant river habitats. As such, the delta may have relatively high fish species diversity compared to lentic reservoir habitats. To compare patterns of fish diversity between the delta and reservoir habitats, we collected fishes in several nursery habitats in both areas using four gear types (seine, gill net, electrofisher, and fyke net) on three occasions (July, August, and September) in 2005. Species richness was higher in the delta (n=34) than the reservoir (n=22). Thirteen species composed more than 1% of delta collections while only four species composed more than 1% of reservoir collections. Species diversity (Fisher's α) was also significantly higher in the delta. Higher species diversity in the delta may be explained by higher habitat diversity. These results suggest that newly forming deltas have the potential to protect and restore fish species diversity because they retain natural river functions such as sediment transport and habitat formation.

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CHAPTER 1. SAUGER EARLY LIFE HISTORY IN THE LEWIS AND CLARK RESERVOIR SYSTEM

Introduction

The sauger *Sander canadensis* is a native, top-level predator and sport fish in the Missouri River (Mestl et al. 2001), but there is little information on the ecology of this species in the Missouri River, particularly the impounded reaches within South Dakota. Widespread declines in sauger populations have been reported elsewhere during the last several decades, including the Great Lakes (Rawson and Schell 1978), the Missouri and Yellowstone rivers in Montana (McMahon and Gardner 2001), Nebraska (Hesse 1994), Tennessee (Pegg et al. 1996), and Wyoming (Baxter and Simon 1970). These extensive declines have prompted researchers to classify sauger as a "species of concern" across much of their range (McMahon and Gardner 2001). Loss of spawning habitat either through river channel alteration (e.g., impoundments) or barriers to migration is a commonly identified factor in these studies that contributes to declining sauger populations. In response to this common theme, researchers have called for restoration of natural riverine function and removal of migration barriers as conservation measures for sauger (Amadio et al. 2005; Jaeger et al. 2005).

While other sauger populations have shown marked declines in recent years, the sauger population in the Lewis and Clark Reservoir system (Gavins Point Dam upstream to Fort Randall Dam) has remained relatively stable (Wickstrom 2004) despite residing in an altered system with an upstream migration barrier. Lewis and Clark Lake maintains about 70 km of riverine habitat above the reservoir. A large and continually growing delta at the upper end of the reservoir, below the confluence with the Niobrara River, attests to the dynamic functions shaping habitat conditions in this system.

The diversity of habitat available in the Lewis and Clark Reservoir system provides a unique opportunity to study sauger ecology. This relatively healthy sauger population is likely maintained because of access to a 70-km stretch of unchannelized riverine habitat, and Lewis and Clark Reservoir has a high turnover rate that may favor sauger over other predators, such as walleyes *Sander vitreus* that are negatively affected by high discharges (Ploskey et al. 1984; Willis and Stephen 1987). Furthermore, sauger may be utilizing the novel delta habitat above Lewis and Clark Reservoir. This area is composed of a vast series of braided, interconnected wetlands with a diverse assemblage of emergent macrophytes surrounding open water pools. Moreover, this is an area that retains some riverine function, such as sediment transport and the creation of habitat. Despite the potential importance of the delta as sauger habitat, little effort has been made to quantify sauger presence there, and in fact, proposals are being evaluated to transport delta sediment out of the system (USACE 2001).

The purpose of this project was to better understand the early life history of sauger in the Lewis and Clark reservoir system in conjunction with other sauger investigations (Graeb 2006) and to identify potential factors influencing survival during this life stage. A better understanding of sauger early life history will allow biologists to better predict how any proposed changes in the management of the Missouri River reservoirs may subsequently affect sauger populations. Factors regulating sauger population structure likely operate over several life stages, but can be particularly important to age-0 fish because year-class strength is often determined during the early life history in fishes (Rice et al. 1987; Willis 1987). As such our objectives were to 1) chronologically track sauger throughout their early life history (egg through juvenile period), and 2) evaluate habitat use and sampling methods for sauger in the Lewis and Clark Reservoir system.

Methods

Study area

The Lewis and Clark Reservoir system (LCRS; Figure 1-1) was formed in 1955 by the closure of Gavins Point Dam (Nelson 1968). The LCRS extends approximately 110 km downstream from Fort Randall Dam to Gavins Point Dam and is the smallest (10,500 ha) and most downstream of the Missouri River mainstem reservoirs, with a maximum depth of only 16.7 m and mean depth of 5 m. It functions primarily as a water control reservoir resulting in low fluctuations in annual water level (mean = 1.1 m; Nelson and Walburg 1977). This system has developed into three distinct habitats over time: the reservoir, delta, and upstream riverine sections. Although sauger utilize all three habitats throughout the year, Nelson (1968) found that spawning occurred in the river during the first decade after dam closure.

The delta is a novel habitat that has been forming since closure of Gavins Point Dam, primarily from deposition of sediment transported by the Niobrara River, a large tributary stream of this system (Johnson 2002). The delta is a dynamic riverine habitat characterized as a braided channel with numerous backwaters, side channels, warmer temperatures, high turbidity, and connectivity to the floodplain. This habitat currently composes approximately 1/3 of the riverine reach (24 km out of 70 km) upstream from Lewis and Clark Reservoir, and is continually expanding downstream into the reservoir (Figure 1). In contrast, the recreational river reach is characterized by a degrading channel with colder temperatures and clear water because of hypolimnetic water releases from Fort Randall Dam, and a loss of floodplain connectivity.

Adult sauger sampling

Sauger spawning habitat was documented during a concurrent study (Graeb 2006), and we focused sampling efforts on locations identified by that study (the Niobrara River mouth and the known spawning site above Santee) for adult sauger collection. We used boat electrofishing to capture 20 adult sauger (13 females and 7 males) during March and April 2004. We determined total length, weight, age, and gonadosomatic index (gonad weight/total weight*100) for each individual. Fish ages were determined from sagittal otoliths. Additionally, the total number of ova (fecundity), mean diameter, and caloric density (estimated with bomb calorimetry) were measured for the gonads of each female.

Larval sauger sampling

We attempted to track the drift of sauger larvae through the remnant reach, delta, and reservoir using standardized sampling at fixed locations using 1-m (diameter) conical nets (ichthyoplankton nets) with 1,000-µm mesh. We sampled the two primary delta tributaries (Bazille Creek and the Niobrara River) by lowering nets from bridges on Nebraska State Highway 12 to determine larval fish contribution to the Missouri River via tributary streams. We

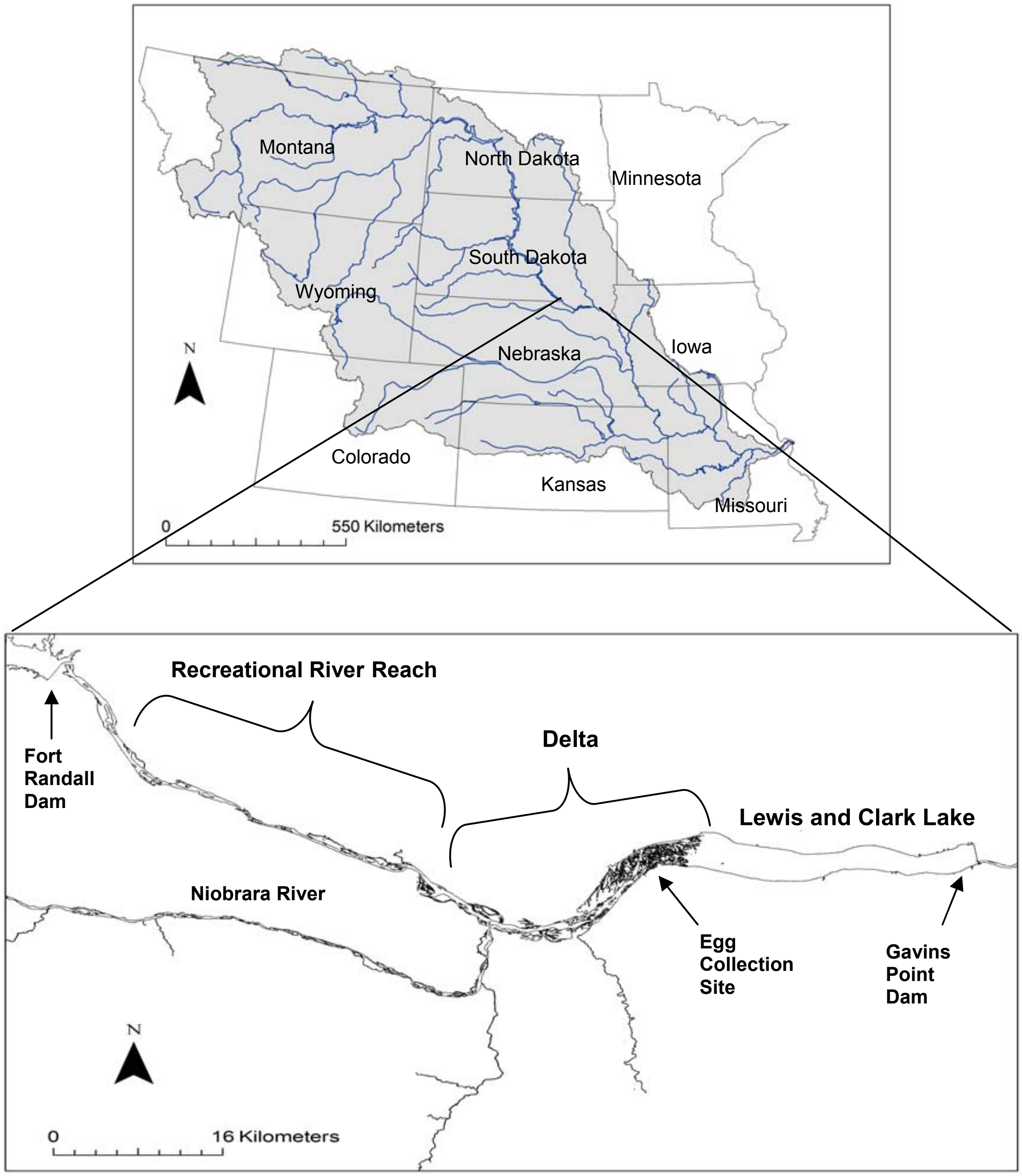

Figure 1-1. Missouri River watershed (top panel) and locations of study areas between Fort Randall Dam and Gavins Point Dam. The egg collection site is a side channel where sauger eggs were consistently collected by Graeb (2006).

collected larval fishes from Verdell, Nebraska to determine larval fish drift from the remnant reach, and sampled main channels in the delta at both Santee, Nebraska, and Springfield, South Dakota. We also sampled two sites in the reservoir (upper and lower) to determine larval sauger abundance and distribution in the reservoir. All riverine sites were sampled by suspending the larval net from an anchored boat for 10 min, or until the net became too fouled to efficiently sample. Reservoir sites were sampled by towing the larval net behind our boat for 10 min.

Juvenile sauger sampling

We collected fishes from nursery habitats at two delta stations (lower delta near Springfield and Santee, and upper delta near Running Water, South Dakota) and two reservoir stations (upper and lower). Sampling was conducted monthly from July through September 2005. Targeted nursery habitats included main channel margins, side channels, backwaters, river channel shoreline embayments, shallow pools among sandbars, and reservoir shorelines. We targeted shallow waters (<1.5 m) in these habitats using 3-mm bar mesh beach seines (3.7 m long, 1.2 m deep), a boat-mounted electrofisher (Coffelt VVP-15 control unit; C-phase, pulsed-DC current), modified-fyke nets (1.5- by 0.8-m frames, 19-mm bar mesh), and experimental gill nets (100 m total length; 50 m of 0.32-cm and 50 m of 0.65-cm bar mesh). We standardized sampling effort during our study; we electrofished 10, 5-min runs per station, made 10 seine hauls (10-15 m) either upstream in areas with current, or perpendicular to shorelines in slack water habitat, and deployed four fyke nets and four gill nets for approximately 4 h per station. Our gear was effective for small-bodied fishes of all ages (e.g., shiners [Cyprinidae]) but for only juveniles of large-bodied fishes (e.g., largemouth bass *Micropterus salmoides*). Thus, incidental catches of adult large-bodied fishes were not included in our analyses. Fishes were immediately preserved in 90% ethanol and later identified to species and enumerated in the lab.

Results and Discussion

Adult sauger collections followed a similar pattern as noted by Graeb (2006) for radio-tagged sauger. During the pre-spawn period (late March-early April), all sauger we collected were located near the mouth of the Niobrara River (Table 1-1), and we did not encounter any sauger near the Santee spawning location. The Niobrara River mouth is thought to be a pre-spawn staging area where sauger congregate in the warmer waters discharged from the shallow, turbid Niobrara River (Graeb 2006). As sauger transitioned into active spawning (mid-late April), sauger were sampled less frequently at Niobrara River, and we collected one adult sauger at near Santee. Similar transitional patterns were observed by Graeb (2006) based on sauger tracked with radio telemetry. The Niobrara River was a pre-spawn staging area, but actual spawning likely occurred at downstream locations throughout the delta, including the Santee location. The delta is likely an important spawning area for sauger and any management actions that perturb or eliminate this habitat should be evaluated for potential effects on sauger spawning.

Table 1-1. Capture date, location, sex, total length, weight, age and gonadosomatic index (GSI) for adult sauger captured during the pre-spawn and spawning periods in the Lewis and Clark delta during 2004. NRM= Niobrara River mouth and “Santee” refers to a confirmed side channel spawning site just upstream from the town of Santee. Individuals without GSI measurements were immature.

Date	Location	Sex	Length	Weight	Age	GSI
3-19	NRM	F	459	867	6	10
3-19	NRM	F	480	1040	4	13
3-19	NRM	F	481	1181	5	12
3-19	NRM	F	513	997	11	13
3-19	NRM	F	463	1179	6	15
3-19	NRM	F	482	997	6	14
3-19	NRM	M	453	740	9	2
3-19	NRM	M	376	455	3	1
3-19	NRM	M	372	472	6	1
3-26	NRM	F	370	425	3	.
3-26	NRM	F	522	1312	6	12
3-26	NRM	F	518	1116	6	12
3-26	NRM	F	398	526	3	12
3-26	NRM	F	305	179	2	.
3-26	NRM	F	195	50	1	.
3-26	NRM	M	387	507	4	1
3-26	NRM	M	375	420	3	1
4-2	NRM	F	377	443	3	.
4-2	NRM	M	372	382	3	1
4-16	Santee	M	362	390	3	1

We collected eight female sauger to examine reproductive biology. Sauger egg quality (defined as egg diameter and caloric density) and fecundity increased with increasing fish length (Figure 1-2). However, egg quality decreased with fish age as the one age-11 female we collected had lower egg quality than age-4 to age-6 females that dominated our samples (Figure 1-3). We are not certain of the actual female age where egg quality begins to decline because of the lack of females between ages 6 to 11 in our sample, but we suggest that females targeted for egg collection should be age 6 or less until further information is obtained to refine that age limit.

Larval sauger are generally indistinguishable from larval walleye until these two species reach larger sizes (D. Snyder, Larval Fish Laboratory, Colorado State University, personal communication) and our larval collections could thus only be identified as *Sander* spp. We collected four *Sander* spp. larvae during our larval fish collections. These larvae were collected in Lewis and Clark Reservoir during mid-late May (5/13 and 5/25), and early June (6/9). We did not collect *Sander* spp. larvae in the riverine, tributary or delta habitats. The round net we used was inefficient at sampling larval fishes in the river and organic matter tended to quickly clog our nets, reducing the amount of water we could filter. We recommend that future work should investigate alternative methods that more efficiently collect larval fishes in riverine environments.

Juvenile sauger were collected over time at several sites throughout the delta and reservoir (Table 1-2). We could not detect patterns of habitat shift as sauger were collected from these sites throughout the summer and fall sampling period. Given that sauger spawn in the riverine habitats of the delta, it is plausible that newly hatched larval sauger are transported throughout the delta and reservoir, depending on flow conditions at time of hatch. Although we collected juvenile sauger throughout the delta and reservoir, we had insufficient sample sizes to detect habitat-specific patterns for growth or relative abundance. The most effective sampling gear for juvenile sauger was electrofishing. We recommend that future research should focus on tracking larval and juvenile sauger throughout the delta and reservoir using electrofishing to determine if spatial patterns in growth and survival exist.

Management Recommendations

This study continued sauger research in the Lewis and Clark Reservoir system and complements information reported by Graeb (2006). It is apparent that this system represents an important sauger population in the Missouri River and should receive future attention. In addition to containing one the most abundant sauger populations in the Missouri River, this system has diverse habitats (e.g., remnant and delta riverine reaches and reservoir) that are representative of many areas of the Missouri River. Thus, future research on the Lewis and Clark sauger population like would enhance conservation of this species throughout its range.

Future research should focus on documenting the transport and habitat use of age-0 sauger through this system. We know that sauger spawning has likely shifted from the upstream remnant reaches to the delta (Graeb 2006), and results from this study indicate that sauger occur in several habitats (delta and reservoir) throughout this system. We did not collect sufficient numbers of sauger to compare habitat specific growth rates, but the results of our gear

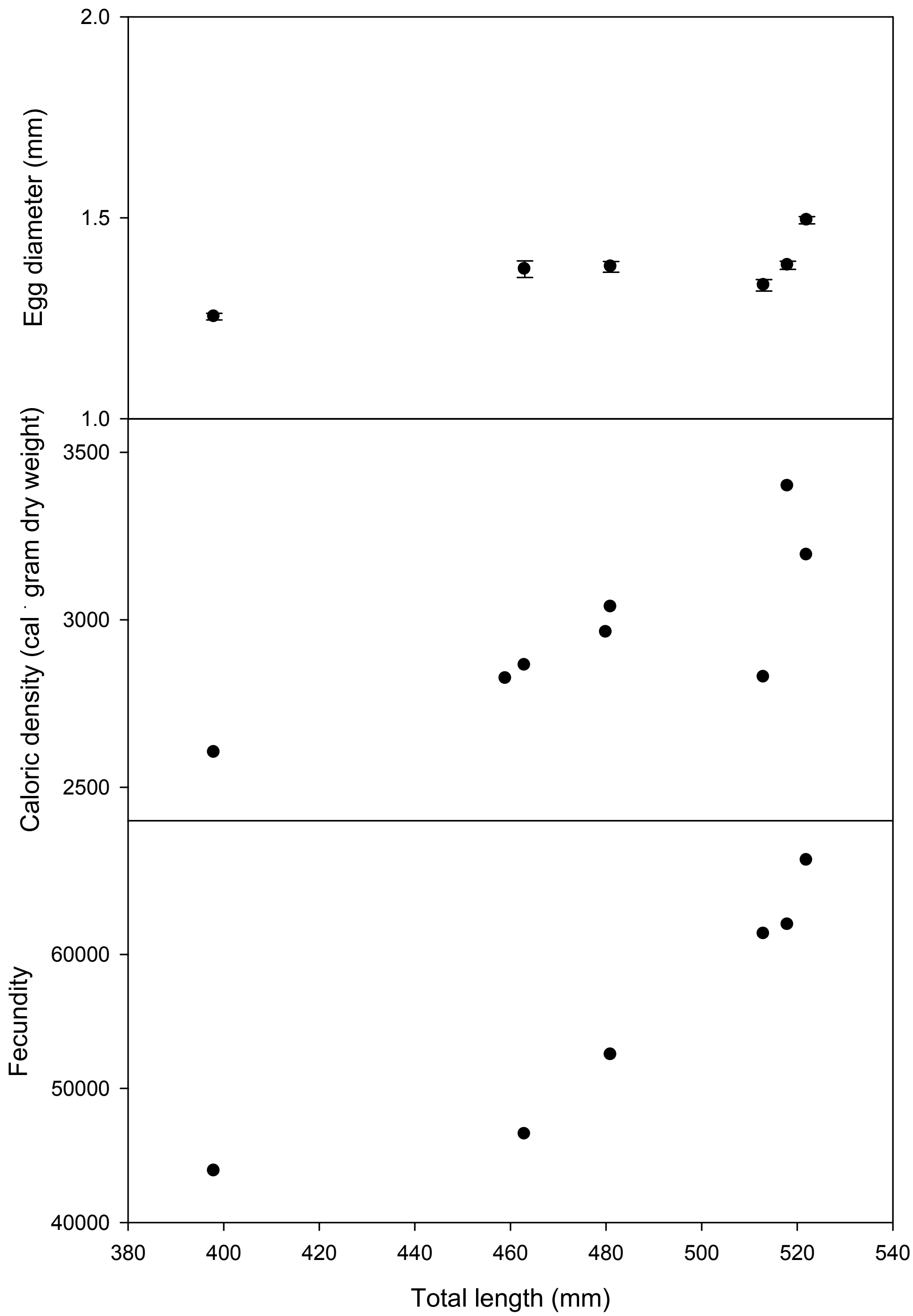

Figure 1-2. Mean egg diameter (±SE), caloric density, and estimated fecundity for female sauger of varying lengths collected from the Lewis and Clark Reservoir system.

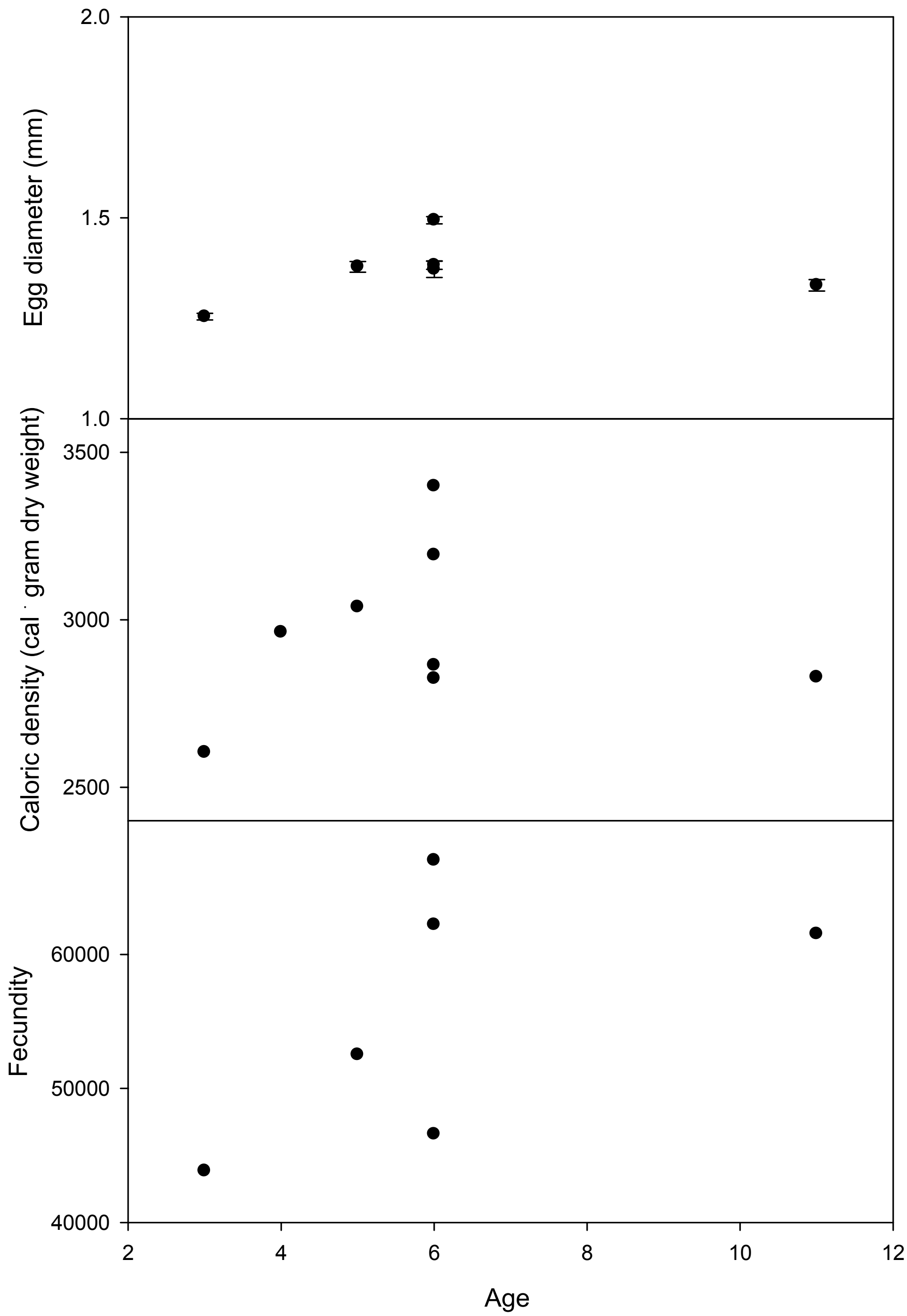

Figure 1-3. Mean egg diameter (±SE), caloric density, and estimated fecundity of female sauger (ages 3 to 11) collected from the Lewis and Clark Reservoir system.

Table 1-2. Capture date, location, gear type, and total length of all *Sander* spp. collected during 2005.

Date	Location	Gear	Total length (mm)
July	Running Water	Seine	69.7
July	Upper reservoir	Gill net	64.8
July	Lower reservoir	Seine	84.5
July	Lower reservoir	Gill net	69.2
July	Upper reservoir	Electrofisher	60.6
July	Upper reservoir	Electrofisher	45.9
July	Upper reservoir	Electrofisher	60.0
July	Springfield	Electrofisher	72.7
July	Running Water	Electrofisher	104.8
July	Springfield	Electrofisher	176.2
July	Springfield	Electrofisher	78.1
July	Springfield	Electrofisher	162.3
August	Upper reservoir	Fyke net	104.4
August	Upper reservoir	Fyke net	74.1
August	Running Water	Electrofisher	103.6
August	Springfield	Electrofisher	90.3
August	Lower reservoir	Electrofisher	105.8
September	Springfield	Electrofisher	137.3
September	Springfield	Electrofisher	106.3
September	Springfield	Seine	131.5
September	Springfield	Electrofisher	177.6
October	Upper reservoir	Fyke net	123.2
October	Upper reservoir	Gill net	114.0
October	Lower reservoir	Seine	157.2
October	Lower reservoir	Fyke net	106.5

comparison suggest that future researchers should focus on electrofishing to study juvenile sauger. This gear was the most efficient sampling gear for juvenile sauger, and had the added bonus of covering larger areas. Sampling larval sauger in the riverine habitats of this system was ineffective using the gears we employed (round larval trawls). This gear did collect larval *Sander* spp. in the reservoir, but in low abundance. We are uncertain if it would be feasible to sample larval sauger in this system without a larger sampling effort in the reservoir and the use of an alternative gear in riverine habitats.

CHAPTER 2. PATTERNS OF FISH DIVERSITY IN DELTA AND RESERVOIR HABITATS OF THE LEWIS AND CLARK SYSTEM

Introduction

Across the world, dams are filling with sediment and as a result, novel delta habitats are forming in many systems (Palmieri et al. 2001). Sedimentation generally occurs over long temporal scales such that evidence of sedimentation is not readily apparent in some systems, but sedimentation will eventually occur in every reservoir constructed (Palmieri et al. 2001). In some systems extensive deltas have already formed, allowing researchers to begin studying the impacts of delta habitats on fish communities in reservoir systems. Lewis and Clark Reservoir, the most downstream of the mainstem Missouri River reservoirs, is one system where sedimentation has occurred relatively rapidly, resulting in the development of a delta. The delta in Lewis and Clark Reservoir is quite extensive (approximately 34 km) and has formed as a result of sediment deposition from a large tributary to this system, the Niobrara River, which drains northern Nebraska from west to east. Aquatic habitats in the delta are diverse with abundant in-channel bedforms such as sand bars, side channels, and backwaters that create a complex riverine landscape. This diverse riverscape has some similarities to the historical Missouri River (e.g., high sediment loads, high width-depth ratios, abundant sand substrate, several wetlands and aquatic vegetation) and habitat conditions are seemingly consistent with recommendations for habitat restoration elsewhere along the Missouri River (Harberg et al. 1993; Hesse and Sheets 1993; Latka et al. 1993). Further, studies have shown that Missouri River reaches with braided river channels and a diversity of aquatic habitats within the floodplain have diverse fish communities (Schmulbach et al. 1975; Kallemeyn and Novotny 1977; Jacobson et al. 2001) and are superior for sport fish production as compared to channelized and/or modified reaches (Groen and Schmulbach 1978). Such reaches also support more diverse invertebrate communities (Morris et al. 1968).

Despite the similarity of the Niobrara River delta to remnant reaches of the Missouri River, fish assemblage studies have primarily focused on tailwater fisheries upstream of or downstream from Lewis and Clark Reservoir and the upstream delta (Walburg et al. 1971; Kallemeyn and Novotny 1977; Schmulbach et al. 1975; Berry and Young 2004), or solely on the reservoir (Walburg 1976; Wickstrom 2000, 2004). Thus, our objective was to compare fish species diversity between the Lewis and Clark delta and reservoir habitats. We hypothesized that reservoir deltas represent additional areas where some ecological characteristics of the historic Missouri River persist (i.e., high species diversity), even though deltas occur in modified habitats (i.e., reservoirs), because they retain natural river functions such as sediment transport and habitat formation, which are disrupted in riverine sections of the Missouri River below dams.

Methods

Lewis and Clark Reservoir, located on the Missouri River along the South Dakota-Nebraska border, is the downstream-most of seven mainstem reservoirs. The reservoir has a surface area of approximately 105 km^2, maximum depth of 16.7 m, and mean depth of 5.0 m (Wickstrom, 2004). Approximately 74 km of riverine habitat exist upstream from the reservoir to Fort Randall Dam. This riverine habitat is composed of two distinct segments: a delta that extends approximately 34 km above the reservoir, and the Missouri National Recreational River reach that encompasses the upper 40 km of this system. Our study focused on the delta and reservoir habitats of this system.

We collected fishes from nursery habitats at two delta stations and two reservoir stations (Figure 1-1). Sampling was conducted monthly from July through September 2005. Targeted nursery habitats included main channel margins, side channels, backwaters, river channel shoreline embayments, shallow pools among sandbars, and reservoir shorelines. We targeted shallow waters (<1.5 m) in these habitats using 3-mm bar mesh beach seines (3.7-m long, 1.2-m deep), a boat mounted electrofisher (Coffelt VVP-15 control unit; C-phase, pulsed-DC current), modified fyke nets (1.5- by 0.8-m frames, 19-mm bar mesh), and experimental gill nets (100 m total length; 50 m of 0.32-cm and 50 m of 0.65-cm bar mesh). We standardized sampling effort during our study; we electrofished 10, 5-min runs per station, made 10 seine hauls (10-15 m) either upstream in areas with current, or perpendicular to shorelines in slack water habitat, and deployed four fyke nets and four gill nets for approximately 4 h per station. Our gear was effective for small-bodied fishes of all ages (e.g., shiners [Cyprinidae]) but for only juveniles of large-bodied fishes (e.g., largemouth bass *Micropterus salmoides*). Thus, incidental catches of adult large-bodied fishes were not included in our analyses. Fishes were immediately preserved in 90% ethanol and later identified to species and enumerated in the lab.

We analyzed fish species diversity as species richness (total number of species, number of common species) and species diversity (Fisher's α). Species richness is a common diversity measure, but it ignores differences in species dominance (MacArthur and MacArthur 1961) and is affected by sample size (Preston 1962). A simple summary of species richness may include incidental (nonresident) species. Thus, we also enumerated species that composed more than 1% (hereafter referred to as common species) of the total delta or reservoir sample (all months combined). Fisher's α provided a more rigorous estimate of species diversity as it represents species of average abundance (neither highly abundant species nor rare species) and is unaffected by sample size (Kempton and Taylor 1974; Magurran 1988). It is derived using the formula: $\alpha = N(1-x) / x$, where x is from iterative solution of: $S/N = (1-x)/x[-\ln(1-x)]$, where S = number of species and N = number of individuals. Fisher's α values have the added benefit of potential for statistical comparison using confidence limits calculated as variance: $\mathrm{Var}(\alpha) = \alpha / -\ln(1-x)$(Magurran, 1988).

Results and Discussion

A total of 9,788 individuals representing 37 fish species were collected (Table 2-1). Overall, species richness was greater at the delta sites (n=34) compared to the reservoir sites (n=22; Table 2-1). Species diversity (Fisher's α) was higher within the delta (mean ± variance, 5.6 ± 0.9) than within the reservoir (mean ± variance, 2.8 ± 0.4). Thirteen fish species were common (< 1% total catch) in the delta (Table I). Four of these (gizzard shad *Dorosoma cepedianum*, emerald shiner *Notropis atherinoides*, white bass *Morone chrysops*, freshwater drum *Aplodinotus grunniens*) were also common in the reservoir. No species was common only in the reservoir.

Table 2-1. Numbers of fish species collected at four stations (two delta, two reservoir) over three sampling periods (July, August, September) in 2005 at Lewis and Clark Reservoir, South Dakota. “Common” fish species (defined as those that composed >1% of the total sample at each habitat type (i.e., delta or reservoir) are denoted by asterisks. Relative species composition (%) is noted in parentheses for each common species; all other species represented less than 1% of the relative composition.

Common name	Scientific name	Delta	Reservoir
Shortnose gar	*Lepisosteus platostomus*	2	3
Gizzard shad	*Dorosoma cepedianum*	270 (11)*	645 (9)*
Central stoneroller	*Campostoma anomalum*	2	0
Red shiner	*Cyprinella lutrensis*	142 (6)*	3
Spotfin shiner	*Cyprinella spilopterus*	391 (16)*	13
Common carp	*Cyprinus carpio*	8	1
Brassy minnow	*Hybognathus hankinsoni*	22	0
Silver chub	*Macrhybopsis storeriana*	0	2
Golden shiner	*Notemigonus crysoleucas*	4	0
Emerald shiner	*Notropis atherinoides*	552 (22)*	5,890 (81)*
River shiner	*Notropis blennius*	163 (6)*	0
Spottail shiner	*Notropis hudsonius*	59 (2)*	19
Sand shiner	*Notropis stramineus*	50 (2) *	0
Bluntnose minnow	*Pimephales notatus*	39 (1)*	0
Fathead minnow	*Pimephales promelas*	16	0
Flathead chub	*Hybopsis gracilis*	76 (3)*	0
Bigmouth shiner	*Notropis dorsalis*	35 (1)*	0
Creek chub	*Semotilus atromaculatus*	0	1
Carpsuckers[1]	*Carpiodes* spp.	168 (7)*	0
Smallmouth buffalo	*Ictiobus bubalus*	12	7
Bigmouth buffalo	*Ictiobus cyprinellus*	15	1
Shorthead redhorse	*Moxostoma macrolepidotum*	10	1
Channel catfish	*Ictalurus punctatus*	5	1
Flathead catfish	*Pylodictus olivaris*	0	1
Northern pike	*Esox lucius*	2	0
White bass	*Morone chrysops*	68 (3)*	542 ((8)*
Rock bass	*Ambloplites rupestris*	4	0
Orangespotted sunfish	*Lepomis humilis*	4	0
Bluegill	*Lepomis macrochirus*	49 ((2)*	11
Smallmouth bass	*Micropterus dolomieu*	25	3
Largemouth bass	*Micropterus salmoides*	86 (3)*	5
White crappie	*Pomoxis annularis*	6	0
Black crappie	*Pomoxis nigromaculatus*	75 (3)*	14
Johnny darter	*Etheostoma nigrum*	100 (4)*	18
Yellow perch	*Perca flavescens*	5	0
Sander[2]	*Sander* spp.	13	13
Freshwater drum	*Aplodinotus grunniens*	34 (1)*	82 (1)*
Total		2,512	7,276

[1] Carpsuckers include river carpsucker *Carpiodes carpio*, quillback *Carpiodes cyprinus*, and highfin carpsucker *Carpiodes velifer*. Previous studies indicated that a majority of carpsuckers found in this region were river carpsuckers, but we were unable to differentiate between these species at small sizes (Schmulbach et al. 1975; Wickstrom 2000, 2004).

[2] Sander include walleye *Sander vitreus*, sauger *Sander canadensis*, and hybrids. Natural hybridization is known to occur in this system (Billington et al. 2004), so it is difficult to distinguish walleye, sauger, and hybrids.

We found higher fish diversity in upstream delta habitats than reservoir habitats in Lewis and Clark Reservoir. Our findings corroborate other studies along the Missouri River in which fish species diversity was high in river reaches with high habitat diversity. Fish and wildlife productivity along the Missouri River declined due to effects of reservoir construction and operation (Funk and Robinson 1974; Whitley and Campbell 1974), but areas that maintained some characteristics of the historical Missouri River remain as strongholds of species diversity and rare native species (Schmulbach et al. 1975; Berry and Young 2004; Everett et al. 2004; Welker and Scarnecchia 2004). Although we are unaware of any previous investigations of fish diversity within delta habitats, our results are similar to a study conducted on plants wherein plant diversity was higher within delta habitats than reservoirs (Johnson 2002). Moreover, Falke and Gido (2006) found higher fish species richness at the confluence of tributary streams with reservoirs than in the tributary streams themselves. These confluence habitats may be similar to the Niobrara River delta.

Our results (34 species in nursery habitats of the delta) compare favorably with results of a much larger study of the fish assemblage in the Missouri River upstream of the delta (43 species; Berry and Young 2004) and with collections from Lewis and Clark Reservoir (37 species; Wickstrom 2000, 2004). Most species found in other studies that we did not collect (pallid sturgeon *Scaphirhynchus albus*, shovelnose sturgeon *Scaphirhynchus platorynchus*, paddlefish *Polyodon spathula*, goldeye *Hiodon alosoides*, burbot *Lota lota*, stonecat *Noturus flavus*) are big river species, unlikely to occupy nursery habitats (Trautman 1981; Pflieger 1997). Others (mimic shiner *Notropis volucellus*, white sucker *Catostomus commersoni*, black bullhead *Ameiurus melas*, grass pickerel *Esox americanus* and green sunfish *Lepomis cyanellus*) were rare in earlier studies. We found one species (bigmouth shiner *Notropis dorsalis*) that was absent from other collections. Thus, the fish assemblage of the delta is similar to that of both the river upstream and reservoir downstream, but nursery habitats of the delta support more species than either of these habitats. We hypothesize that nursery habitats in the delta are important for fish populations of the entire Lewis and Clark Reservoir system.

We attribute high species diversity in nursery habitats of the delta compared to those of the reservoir to habitat diversity. For example, the prevalent delta inhabitants red shiner *Cyprinella lutrensis*, spotfin shiner *Cyprinella spiloptera*, river shiner *Notropis blennius*, and river carpsucker *Carpiodes carpio* primarily inhabit flowing waters (Trautman 1981; Pflieger 1997). In contrast, the prevalent spottail shiner *Notropis hudsonius*, largemouth bass *Micropterus salmoides*, black crappie *Pomoxis nigromaculatus*, and johnny darter *Etheostoma nigrum* are characteristic of habitats with little or no current (Trautman 1981; Pflieger 1997). The presence of interspersed fluvial habitat and slackwater habitat in the delta evidently contributes to higher overall species diversity by supporting both flowing water and slackwater fishes. Further, the prevalence of dominant reservoir fishes (gizzard shad, emerald shiner, white bass, freshwater drum) in the delta suggests a link between delta and reservoir fish communities.

Our fish collection occurred only during summer and early fall because we were especially interested in including age-0 fishes in our assessment. However, temporal variability in fish species composition may occur throughout the early growing season (spring) and overwinter periods that may affect patterns of fish diversity. Future studies that incorporate expanded temporal coverage of delta and reservoir habitats will increase our understanding of the relative importance of these habitats.

Management Implications

Fish conservation and management along the Missouri River is complex due to the changes and diversity in regulatory agencies involved (McClendon 1976; Hesse et al. 1989; Galat et al. 2005). However, many researchers agree that habitat diversity and a complex riverine landscape correspond with higher ecological productivity and fish species diversity in the Missouri River (Morris et al. 1968; Funk and Robinson 1974; Schmulbach et al. 1975; Kallemeyn and Novotny 1977; Groen and Schmulbach 1978; Hesse et al. 1988; Brown and Coon 1994; Galat et al. 1998; Fisher and Willis 2000; Welker and Scarnecchia 2003; Dieterman and Galat 2004). We contend that reservoir deltas may play a role in Missouri River fish conservation and management by increasing aquatic habitat diversity via passive rehabilitation (*sensu* Jacobson et al. 2001) because the natural processes of sediment transport and habitat formation are present and dynamic in the delta. As a result, reservoir deltas may increase management options and provide unique opportunities for studies of ecological processes.

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